Air Cooling Studies for the ePIC Silicon Vertex Tracker

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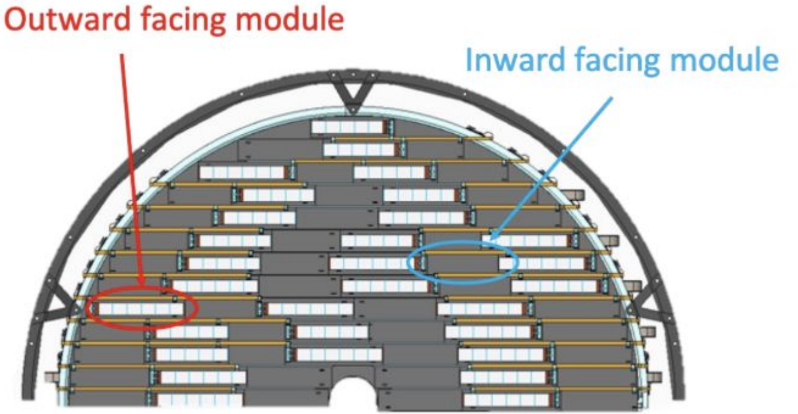
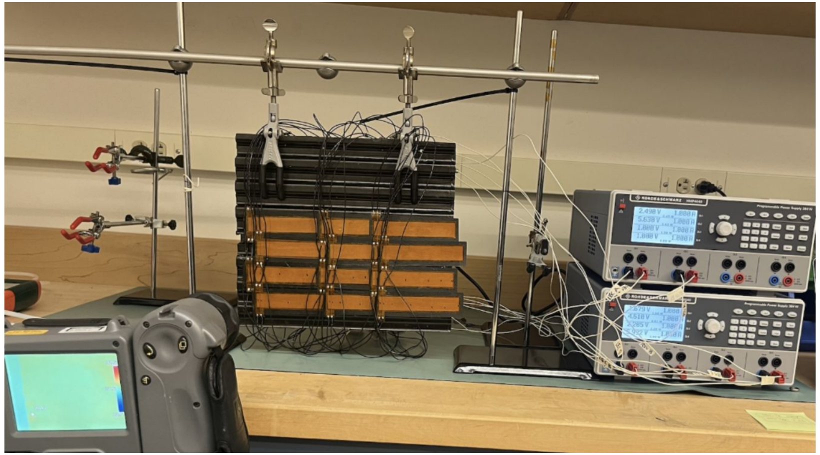
10/6/25

Large Thermal Test Piece

- The large thermal test piece gives us a very rich dataset
- However, this geometry does not mirror what the disk will look like





Front View

- The LECs on the test piece all face the same direction, this is not the case for the disk- how can we make a configurable model?

Modelling Considerations

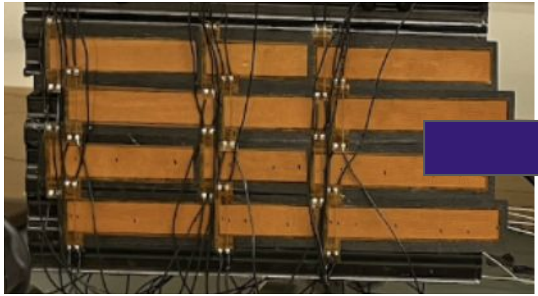
Key Considerations

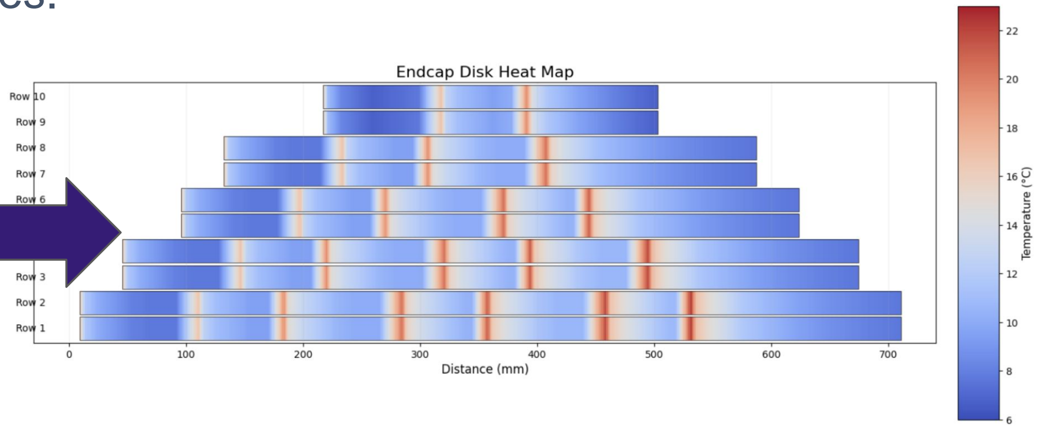
- Variable LECs
- Variable spacing / orientations

Attempting to Extrapolate

- Any model directly from the test piece will demonstrate the same very hot midsection, and cooler edges.

The orientation of the sensors switches in the middle

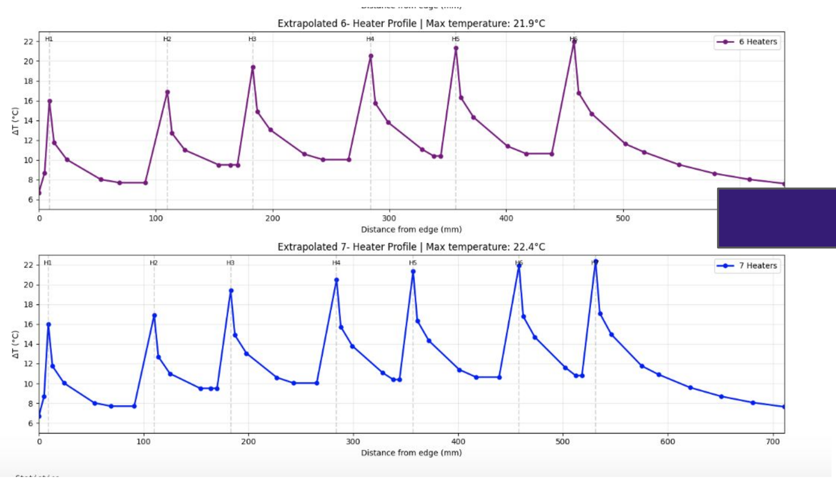


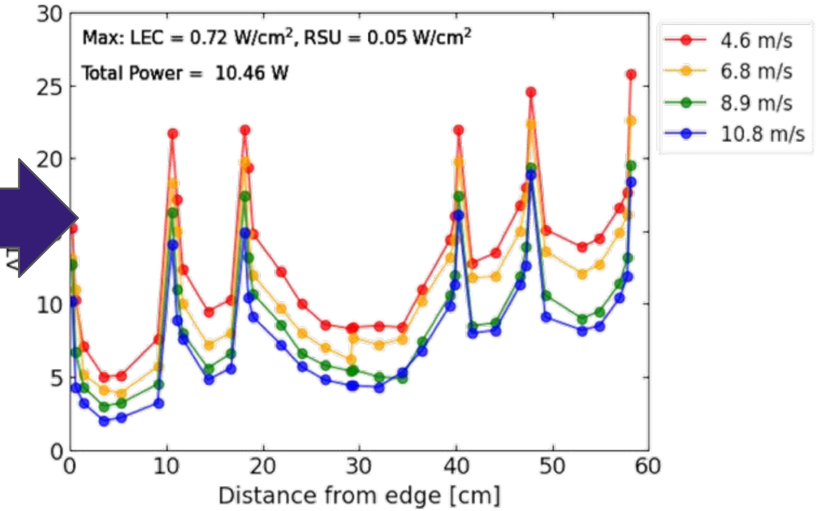


Modelling Considerations

Revisiting the Approach

- Clearly, the left approach of extrapolating is not sufficient for estimating what a full disk will look like
- Refocus for a moment on modelling a single row in **any** configuration

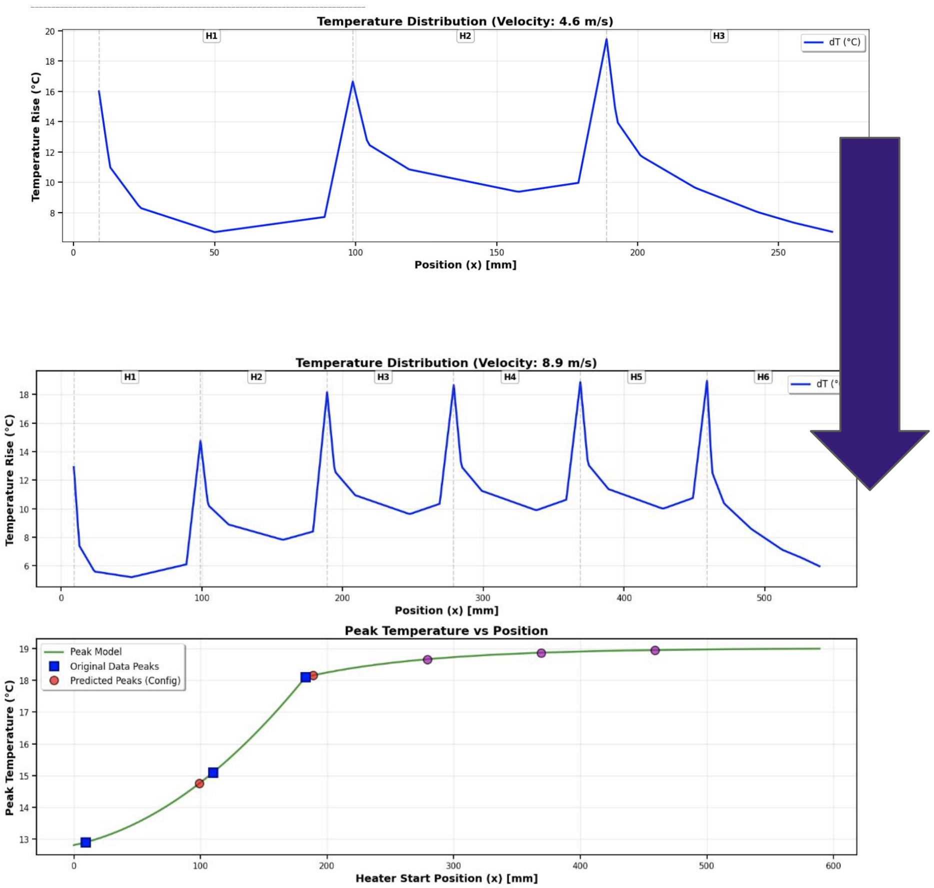




Single Row Modelling

Revisiting the Approach

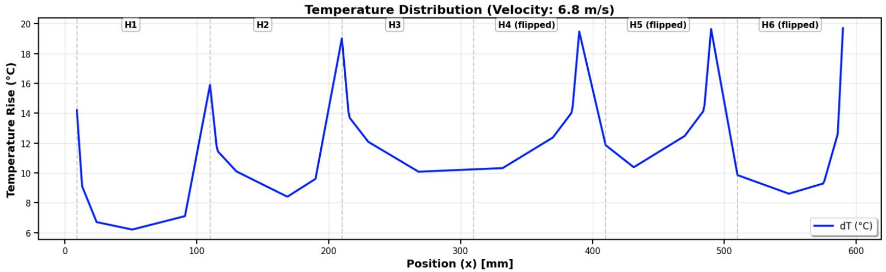
- Reasonable number to keep in mind: With **no forced convection**, for a single row, I saw a dT of 22-23C at **Max power**
- Temperature increase saturates, so seeing a dT > 25 == ineffective model
- I fit a quadratic polynomial to the three observed peak temperatures as a function of heater start position
- For extrapolation beyond the last measured heater, the model transitions to an exponential saturation function

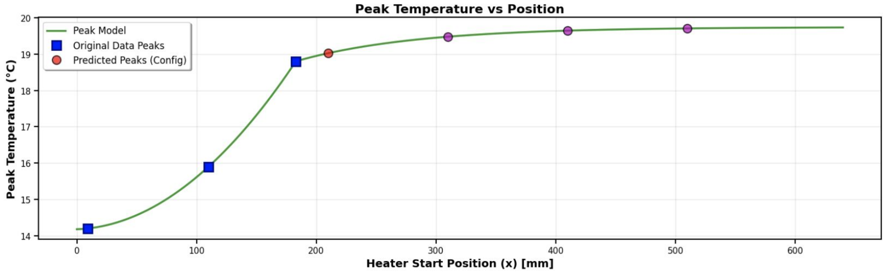


Single Row Modelling

Revisiting the Approach

- The exponential saturation function that asymptotically approaches a physically bounded maximum temperature (preventing unrealistic thermal runaway predictions)
- Each **extrapolated** heater's temperature profile is then generated by scaling its template profile such that the maximum temperature matches the predicted peak value at its upstream edge.
- This allows us to **flip** any given heater as we have an expected peak temp at any given point





Variables to Consider in a Full Model

What To Include?

- Nearest Neighbor Interactions
- Next to Nearest Neighbor Interactions
- Effects from Neighbors & Next to nearest neighbors on the other side
- Variable Power Densities
- Variable Air speeds
- The following plots are plots of dT
  - (add ~23 degrees to max dT for an estimate of the absolute T)

See previous talks for those measurements / calculations!

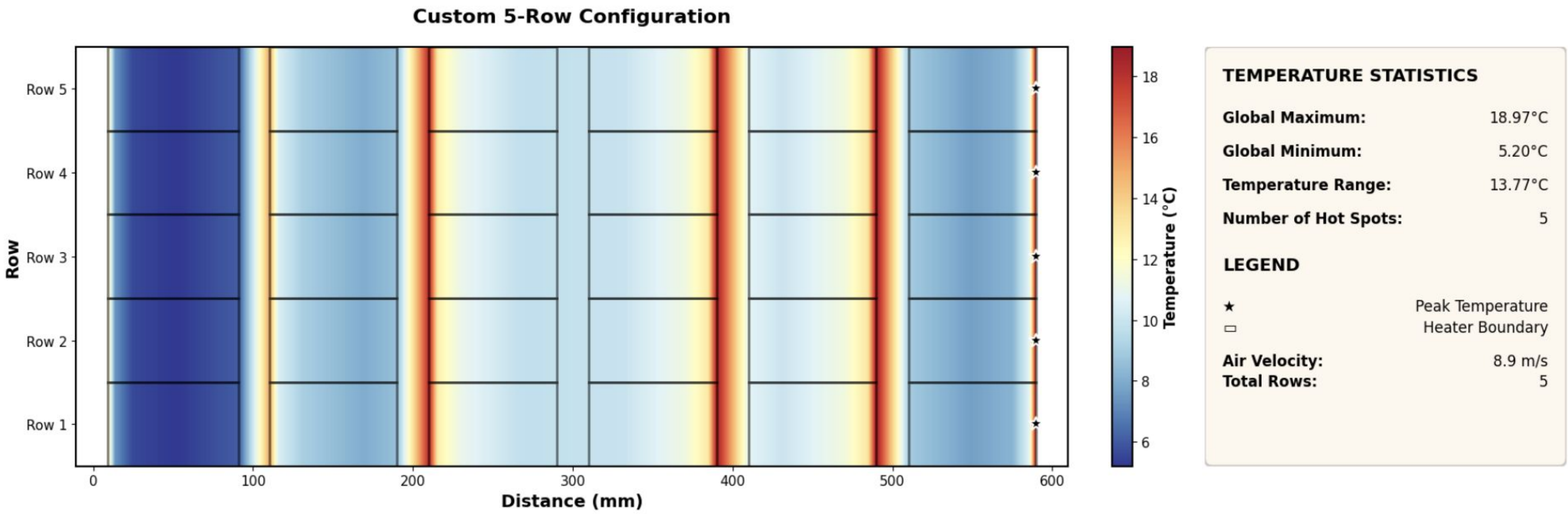
Code
\url

Multi Row Modelling

Re-implementing the full scale model

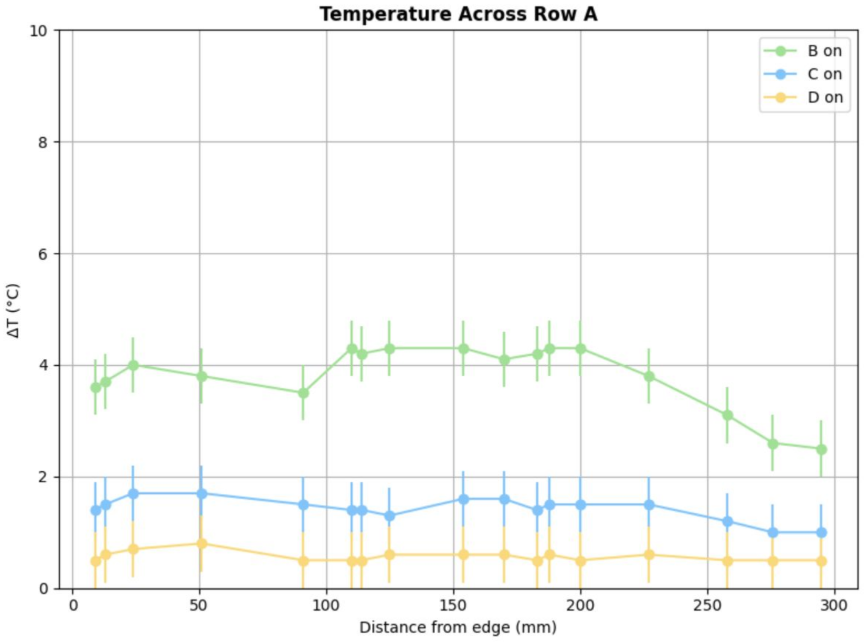
- Need to be able to specify **any** (useful) configuration

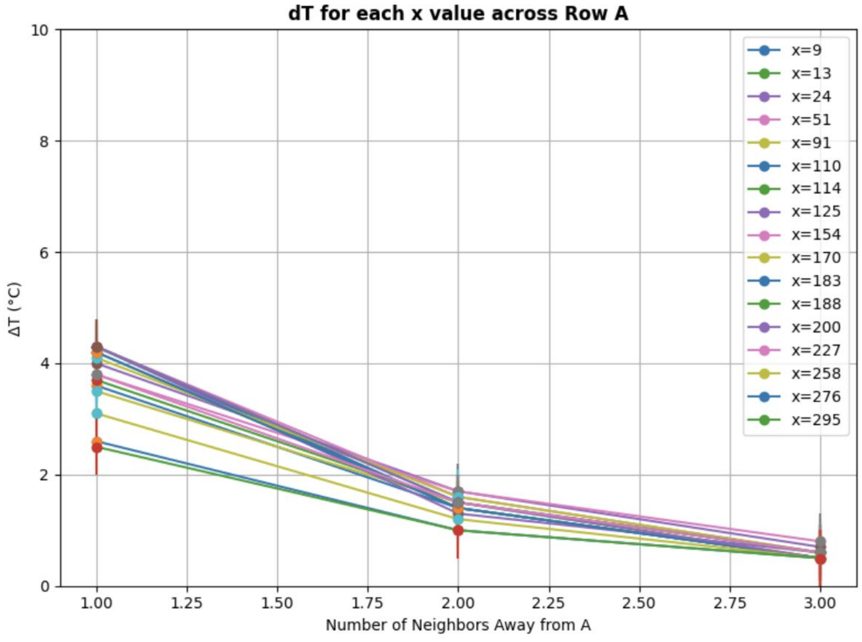
```
custom_row_config = [{
    'heaters': [
        {'start': 9, 'end': 91, 'flipped': False},
        {'start': 110, 'end': 190, 'flipped': False},
        {'start': 210, 'end': 290, 'flipped': False},
        {'start': 310, 'end': 390, 'flipped': True},
        {'start': 410, 'end': 490, 'flipped': True},
        {'start': 510, 'end': 590, 'flipped': True}
    ],
    'offset': 0
}]
```



Neighbor Modelling: Summary

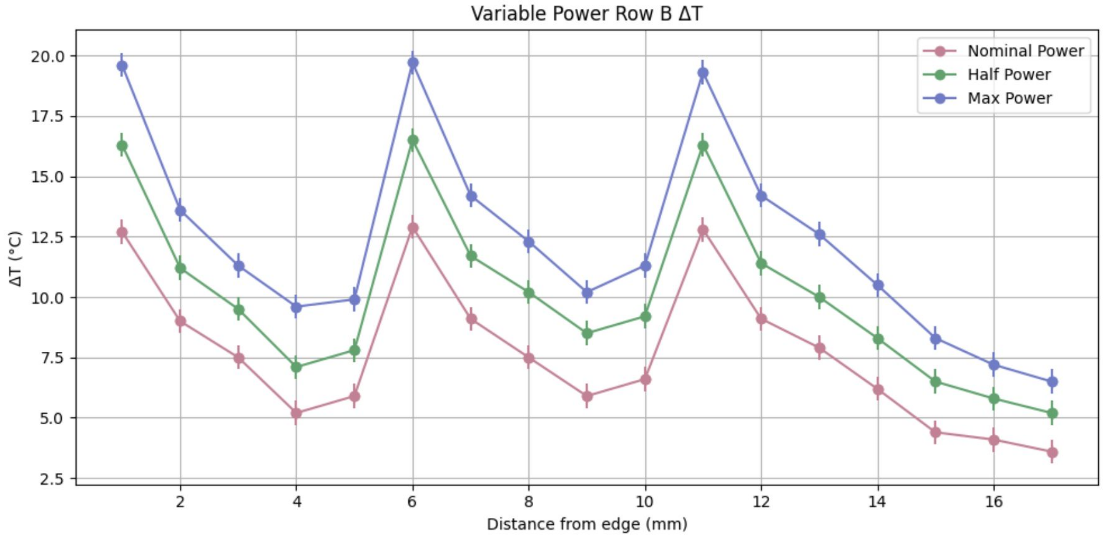
- Plot of # of neighbors away vs dT suggests exponential decay
- Decay constant different for same-side vs opposite side
- Assume symmetry of top & bottom rows





Air Speed & Power Density: Summary

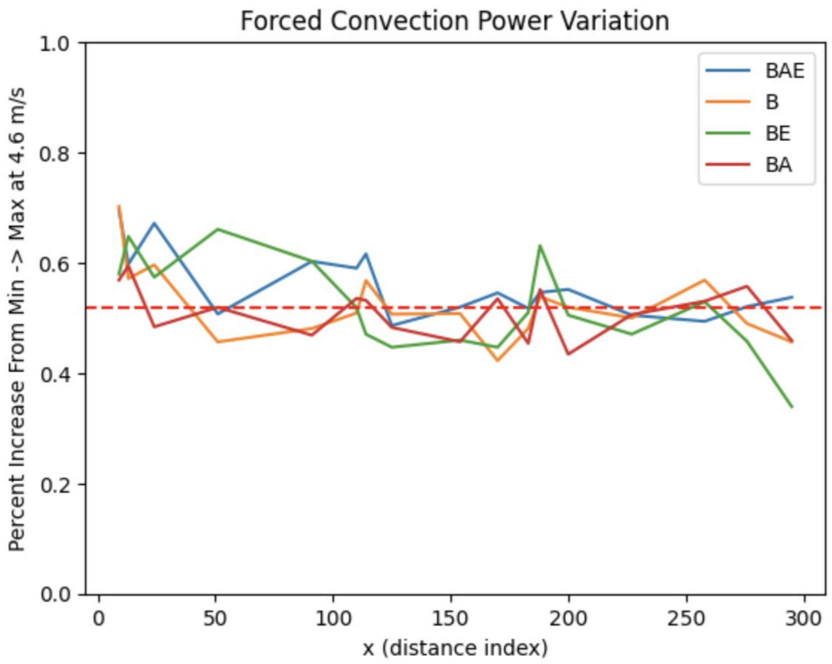
- Plot of variable power vs dT suggests linear decay
- Is this true with forced convection and neighbors?



Estimated power density for LECs has changed since my analysis was done

Air Speed & Power Density: Summary

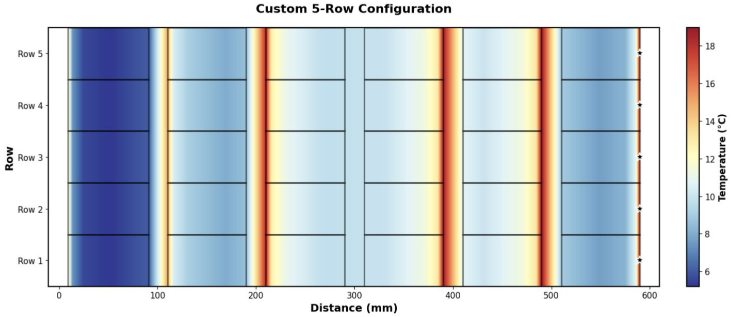
- Done at 4.6 m/s, measuring across B
- Data quite variable
- Max power density was [0.72, 0.05] W/cm², and a change of [+0.245, +0.019] from this baseline produces roughly a +52% temperature increase
- Consistent with previous measurements
- Measurements at new expected power density should be considered, only really needed for a single row

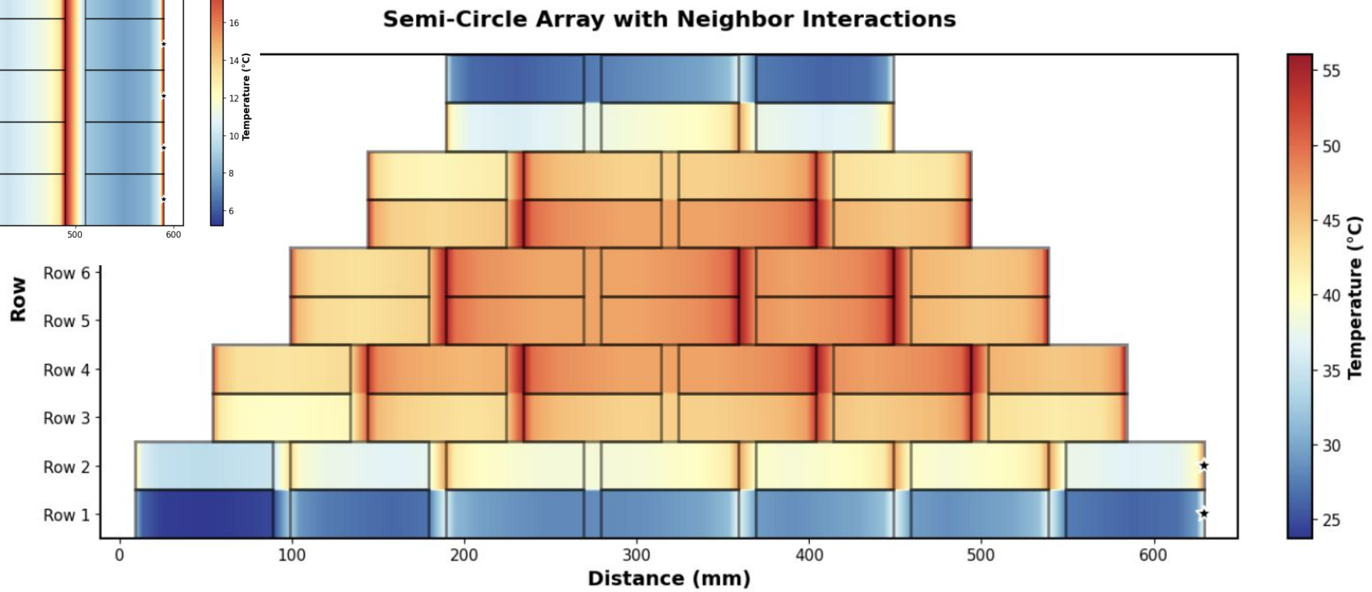


Full Disk Modelling

Including Interactions

Code also outputs temperature at each point, the global maximum, and inputted variable

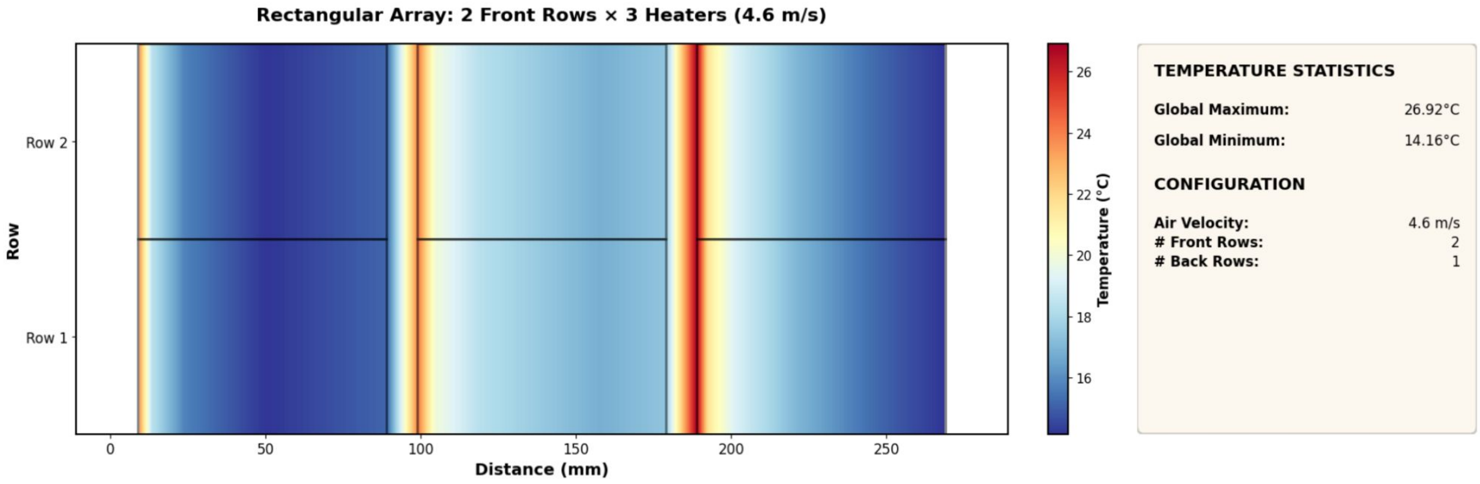




Comparison with Data

What can I predict?

- The model's only data input is that of a single row profile at various airspeeds
- The model **does not know** the data for multiple rows, all of this is calculated
- Here I compare a configuration of 2 front rows and a back row at max power at 4.6 m/s (on the test piece BAE)



Comparison with Data

What can I predict?

- My goal was to accurately predict the **maxima** which is the most important thing the model should spit out
- The model clearly struggles with the minima RSU regions, which have higher error